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Charmless Two-body B Decays: A Global Analysis with QCD factorization

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Abstract

In this paper, we do a global analysis of $B \to PP$ and PV decays with QCD factorization approach. It is encouraging to observe that the predictions of QCD factorization are in good agreement with the experiments. The best fit γ is around 79°. The penguin-to-tree ratio $|P_{\pi\pi}/T_{\pi\pi}|$ of $\pi^+\pi^-$ decays is prefered to be larger than 0.3. We also show the confidence levels for some interesting channels: $B^0 \to \pi^0\pi^0$, K^+K^- and $B^+ \to \omega\pi^+$, ωK^+. For $B \to \pi K^*$ decays, they are expected to have smaller branching ratios with more precise measurements.

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1 Introduction

The charmless two-body B decays play a crucial role in determining flavor parameters, especially the CKM angle γ and α. With the successful running of B factories, many charmless decay channels have been measured with great precision. However, since hadronic B decays involve three separate scales: m_W, m_b and Λ_{QCD} where perturbative and non-perturbative effects are entangled, it is highly nontrivial to relate flavor parameters to experimental observable.

Recently, the theorists have made much progress on non-leptonic B decays: three novel methods, QCD factorization (QCDF)[1], perturbative QCD approach (pQCD)[2] and charming penguin method[3], have been proposed. These methods have very different understanding on B decays: For both QCDF and pQCD approach, factorization theorem is proved for non-leptonic B decays in leading power expansion, i.e. short-distance physics related to the scales M_W and m_b can be separated from long-distance physics related to the hadronization scale Λ_{QCD}, and the long distance part can be parameterized into some universal non-perturbative parameters. In this sense, they are similar. But pQCD implements the Sudakov form factor to suppress the end-point contributions and prove the factorization theorem in which the form factors are perturbatively calculable. Notice that Sudakov form factor itself is a perturbative quantity, it is rather radical and controversial to prove the factorization using Sudakov form factor. While in QCDF, the form factors are believed to be non-perturbative parameters. Therefore these two methods have completely different power behaviors for B decays. Their predictions on B decays are also quite different. For instance, pQCD generally predicts large strong phases and direct CP violations, while QCDF favors small direct CP violations in general because of the α_s-suppressed strong phases. Charming penguin process, i.e. $(b\bar{q}) \to (c\bar{q})(\bar{c}s) \to (q'\bar{q})(\bar{q}'s)$ might be potentially important for penguin-dominant decays because it is doubly enhanced by CKM factors and Wilson coefficients. The characteristic of charming penguin method is that, the soft-dominance charming penguin plays an indispensable role for penguin-dominant decays. While in QCDF, charm penguin contributions are hard dominance and therefore perturbatively calculable according to naive power counting rules.

Now BaBar and Belle have accumulated copious data, and will record much more data, on non-leptonic B decays. Thus it should be highly interesting to compare the predictions of these methods with the precise experimental measurements. We gave the QCDF predictions on B $\to$ PP and PV decays in recent works [4, 5]. With the experimental data at that time, our results prefer somewhat larger angle γ. For PV decays, the QCDF predictions are only marginally consistent with the experimental observation for some decay channels. Notice that the QCDF predictions contain large numerical uncertainties due to the CKM matrix elements, form factors and annihilation parameters, and furthermore, the uncertainties of various decay channels are strongly correlated to each other, we are stimulated to do a global analysis in this paper to check the consistency between the predictions of QCDF and the updated experimental results. Beneke *et al.* [7] have done a global analysis including $\pi\pi$, πK modes with the QCDF approach, and shown a satisfactory agreement between the QCDF predictions and experiments. While in this work, we shall consider not only $B \to PP$ decays, but also $B \to PV$ channels. Thereby, as we would see later, it leads to some new interesting results.

One of the most impressive predictions of the QCDF approach is that, direct CP violation of charmless B decays should be small because the strong interaction phase arises solely from radiative corrections. Up to now it is well consistent with the measurements of BaBar and Belle. However, the power corrections which may also contribute to strong phases are numerically comparable with the radiative corrections. Notice that the power corrections are difficult to estimate because they generally break factorization. It means that the predictions of QCDF on direct CP violations are probably qualitative. Therefore in this paper we will not consider the experimental results on direct CP violations.

Our global fit shows that QCDF has an excellent performance on $B \to PP$ (two light pseudoscalars) decays except for the channel $B^+ \to \eta K^+$. But we do not worry about it because of the hard-to-estimate contributions from the digluon mechanism and the potential large power corrections in this channel. The CKM angle γ is prefered to be around 79° which is slightly larger but still consistent with the standard CKM global analysis[6]. We also discuss the prefered range of the penguin-to-tree ratio $|P_{\pi\pi}/T_{\pi\pi}|$ [1] which is crucial for the extraction of angle α. For $B \to PV$ (one pseudoscalar, one vector) decays, QCDF has also good performance where the annihilation topology plays an important role especially for penguin-dominated decays. But for $B \to \pi K^*$ channels, the QCDF results seem smaller compared with the experimental measurements. However, presently there are large experimental errors on these channels, so it would be very interesting for BaBar and Belle to update their measurements with higher precison on these decay modes. Based on the global fit, we also give the confidence levels for some interesting decay channels: $B^0 \to \pi^0\pi^0$, K^+K^- and $B^+ \to \omega\pi^+$, ωK^+.

This paper is organized as follows: in Section II, we will first recapitulate the mainpoint of QCD factorization for charmless two-body B decays. In Section III, the relevant input parameters are discussed. Then the numerical results of the global fit and brief remarks are presented in Section IV. Section V is devoted to the conclusions.

2 QCD Factorization for charmless B decays

As we know, charmless B decays contain three distinct scales: $M_W \gg m_b \gg \Lambda_{QCD}$. To go beyond the naive model estimation, it is important to show that the physics of different scales can be separated from each other. This process is generally called "factorization" .

It is well known that, with the help of operator product expansion and renormalization group equation, the effective Lagrangian can be obtained, in which the short-distance effects involving large virtual momenta of the loop corrections from the scale M_W down to $\mu = \mathcal{O}(m_b)$ are cleanly integrated into the Wilson coefficients. Then the amplitude for

[1] the defination of the penguin-to-tree ratio $|P_{\pi\pi}/T_{\pi\pi}|$ for $B_d^0 \to \pi^+\pi^-$ decay is [7]

$$\mathcal{A}(B_d \to \pi^+\pi^-) \propto \; e^{-i\gamma} + \frac{P_{\pi\pi}}{T_{\pi\pi}},$$

$$\frac{P_{\pi\pi}}{T_{\pi\pi}} = \frac{-1}{R_b} \frac{(a_4^c + r_\chi^\pi a_6^c) + (a_{10}^c + r_\chi^\pi a_8^c) + r_A[b_3 + 2b_4 - \frac{1}{2}(b_3^{EW} - b_4^{EW})]}{(a_1 + a_4^u + r_\chi^\pi a_6^u) + (a_{10}^u + r_\chi^\pi a_8^u) + r_A[b_1 + b_3 + 2b_4 - \frac{1}{2}(b_3^{EW} - b_4^{EW})]},$$

where $R_b = \frac{|V_{ud}V_{ub}^*|}{|V_{cd}V_{cb}^*|} = \sqrt{\bar\rho^2 + \bar\eta^2}$, and $r_A \simeq \frac{f_B f_\pi}{m_B^2 F_0^{B\to\pi}}$.

the decay $B \to M_1 M_2$ can be expressed as [9]:

$$\mathcal{A}(B \to M_1 M_2) = \frac{G_F}{\sqrt{2}} \sum_i \sum_{q=u,c} \lambda_q C_i(\mu) \langle M_1 M_2 | Q_i(\mu) | B \rangle, \tag{1}$$

where λ_q is a CKM factor, $C_i(\mu)$ is the Wilson coefficient which is perturbatively calculable from first principles, $\langle M_1 M_2 | Q_i(\mu) | B \rangle$ is a hadronic matrix element which contains physics from the scale $\mu = \mathcal{O}(m_b)$ down to Λ_{QCD}. In a sense, this process may be called as "first step factorization". But it is still highly non-trivial to estimate the hadronic matrix elements reliably because the perturbative and non-purturbative effects related to m_b and Λ_{QCD} are strongly entangled.

Three years ago, Beneke, Buchalla, Neubert and Sachrajda put forward the QCDF approach in the heavy quark limit for $B \to \pi\pi$ [1]. They show that, neglecting power corrections in $1/m_b$, the hadronic matrix elements can be factorized into hard radiative corrections and non-perturbative part parameterized by the form factors and meson light cone distribution amplitudes. In the following we will outline their reasoning.

2.1 QCDF in the heavy quark limit

Firstly, we need to have some knowledge about the endpoint behavior of the light cone distribution amplitudes (LCDAs) of the mesons. At the scale of m_b, the LCDAs of the final light mesons, for example $\phi(x)$ of π or K mesons, should be similar with the asymptotic form. Therefore it is reasonable to assume that the endpoint of the LCDAs of the light mesons is suppressed by Λ/m_b. For B meson, the spectator quark is assumed to be soft and no hard tail, i.e., $\phi(\xi) \sim m_b/\Lambda$, for $\xi < \Lambda/m_b$ and $\phi(\xi) = 0$, for $\xi > \Lambda/m_b$. With the above assumptions, form factor is argued to be nonperturbative dominance, thereafter naive power counting rules are constructed and the leading power radiative contributions in $1/m_b$ can be identified (see Fig.1).

Notice that, in Fig.1, the emission meson from decay vertex carries large energy and momentum (about $m_B/2$) and therefore can be described by leading twist-2 LCDA in the leading power approximation. For factorization to be held, these radiative contributions should be hard dominance. For vertex corrections (Fig.1(a)-(d)), every individual diagram contains infrared divergence, but these infrared divergence are canceled after summation. This cancellation is not accidental. Intuitively, $q\bar{q}$ pair of the energenic emission meson can be viewed as a small color dipole. For soft gluon, a small dipole just likes a color singlet, so the emission meson decouples with the soft gluon interaction. This argument is well-known as "color transparency" [10]. Technically, not only soft divergence but also collinear divergence are canceled. For penguin corrections (Fig.1(e)-(f)) and hard spectator scattering (Fig.1(g)-(h)), since the endpoint of the twist-2 LCDA of the light meson is Λ/m_b suppressed, it is not difficult to show hard dominance. So factorization does hold in the heavy quark limit, the corresponding formula can be explicitly expressed as

$$\langle M_1 M_2 | Q_i | B \rangle \quad = \quad F^{B \to M_2}(0) \int_0^1 dx T^I_{i1}(x) \Phi_{M_1}(x) + F^{B \to M_1}(0) \int_0^1 dx T^I_{i2}(y) \Phi_{M_2}(y)$$

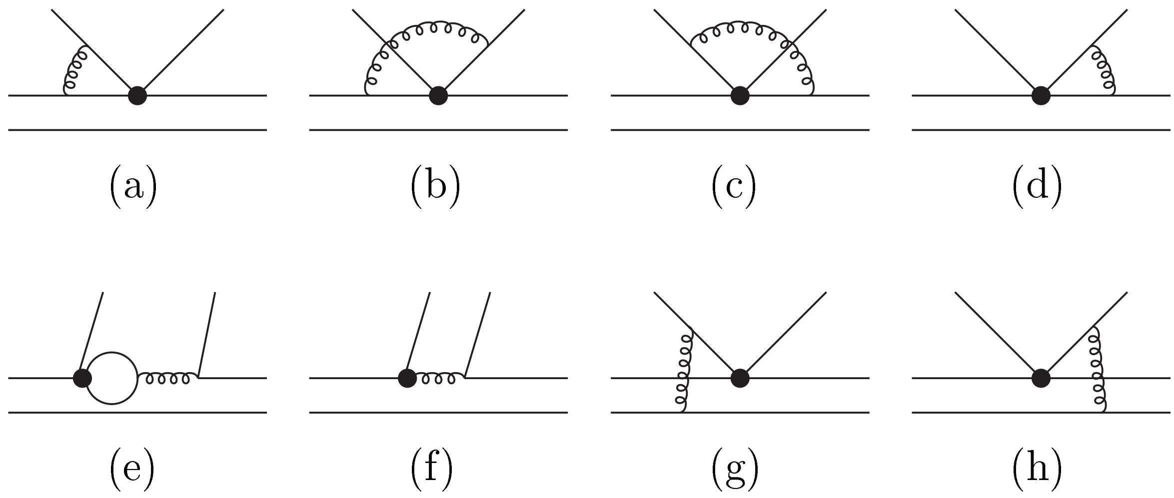

Figure 1: Order of α_s corrections to the hard scattering kernels. The upward quark lines represent the emission meson from b quark decay vertex. These diagrams are commonly called vertex corrections, penguin corrections and hard spectator scattering diagrams for Fig.(a)-(d), (e)-(f) and (g)-(h) respectively.

$$
\begin{aligned}
& + \int_0^1 d\xi dx dy T_i^{II}(\xi, x, y) \Phi_B(\xi) \Phi_{M_1}(x) \Phi_{M_2}(y) \\
= \quad & \langle M_1 M_2 | J_1 \otimes J_2 | B \rangle \cdot [1 + \sum r_n \alpha_s^n + \mathcal{O}(\Lambda_{QCD}/m_b)]. \qquad (2)
\end{aligned}
$$

In the above formula, $\Phi_B(\xi)$ and $\Phi_{M_i}(x)(i = 1, 2)$ are the leading-twist wave functions of B and the light mesons respectively, and $T_i^{I,II}$ denote hard scattering kernels which is perturbatively calculable. The readers may resort to Ref.[11] for more details.

One of the most interesting results of the QCDF approach is that, in the heavy quark limit, strong phases are short dominance and arise solely from vertex and penguin corrections which are at the order of α_s. It means that, for charmless hadronic decays, direct CP violations are generally small because strong phases is α_s-suppressed compared with the leading "naive factorization" contributions. But in principle power corrections may also contribute to strong phases, and numerically Λ_{QCD}/m_b is comparable with α_s. Furthermore, there is no known systematic way to estimate power suppressed contributions (note that soft-collinear effective theory [12] may be a potential tool), so QCDF could only predict strong phases qualitatively.

2.2 Chirally enhanced power corrections

The above discussions are based on the heavy quark limit, i.e. power corrections in $1/m_b$ are assumed to be negligible. Then the question is, for phenomenological application, whether it is a good approximation. There are various sources which may contribute to power corrections in $1/m_b$, examples are higher twist distribution amplitudes, transverse momenta of quarks in the light meson, annihilation diagrams etc.. At first sight, power corrections seem really small because they are suppressed by $\Lambda_{QCD}/m_b \simeq 1/15$. However, it is not true. For instance, the contributions of operator Q_6 to decay amplitudes would formally vanish in the strict heavy quark limit. But it is numerically very important in penguin-dominated B rare decays, such as the interesting $B \to \pi K$ decays. This is because that Q_6 is always multiplied by a formally power suppressed but chirally enhanced factor $r_\chi = \frac{2m_P^2}{m_b(m_1+m_2)} \sim \mathcal{O}(1)$, where m_1 and m_2 are current quark masses. Another example is annihilation topology (Fig.2), which importance is noticed first in pQCD method [2]. Therefore phenomenological applicability of QCD factorization in B rare decays requires at least a consistent inclusion of chirally enhanced corrections and annihilation contributions.

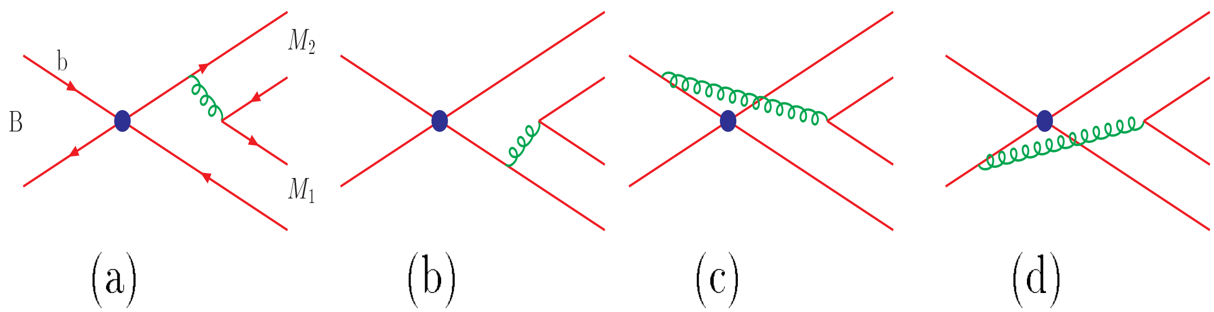

Figure 2: Order of α_s corrections to the weak annihilations.

Chirally enhanced corrections arise from twist-3 light-cone distribution amplitudes, thus the final light mesons should be described by leading twist and twist-3 distribution amplitudes. Then we need to re-demonstrate that the leading power radiative corrections (Fig.1) are still dominated by hard gluon exchange. Unfortunately it is not true for hard spectator scattering which contains logarithmic divergence in the end-point region. The similar divergence also appears in the annihilation contributions. It means that, strictly speaking, factorization does not hold for chirally enhanced corrections and annihilation topology. The readers may refer to Refs. [7, 13] for more technical details. Phenomenologically, Beneke *et al.* [7] introduce a model parametrization for the end-point divergence:

$$X_{A,H} = \int_0^1 \frac{dx}{x} = \ln \frac{m_B}{\Lambda_h}(1 + \rho_{A,H}\, e^{i\phi_{A,H}}), \tag{3}$$

where X_A denotes annihilation contribution, and X_H denotes hard spectator scattering. We will follow their way in this paper.

For the rest power corrections, it is argued to be generally small [14] based on a model estimation with the renormalon calculus.

With the above discussions, the decay amplitudes can be written as

$$\mathcal{A}(B \to M_1 M_2) = \frac{G_F}{\sqrt{2}} \sum_{p=u,c} \sum_{i=1}^{10} v_p (a_i^p \langle M_1 M_2 | O_i | B \rangle_f + f_B f_{M_1} f_{M_2} b_i), \tag{4}$$

where $\langle M_1 M_2 | O_i | B \rangle_f$ is the factorized hadronic matrix element which has the same definition as that in the naive factorization approach. For the explicit expressions of QCD coefficients a_i and annihilation parameters b_i, the readers may refer to Refs. [4, 5, 7].

3 Input parameters

The decay amplitude for $B \to M_1 M_2$ depends on various parameters, such as the CKM matrix elements, decay constants, form factors, renormalization scale μ, LCDAs and so on. Notice that although the predictions of QCDF are formally scale-independent at one-loop order, numerically there are still small residual dependence. In the global fit, the scale μ is varied from $m_b/2$ to $2m_b$. For the rest of the parameters, we will specify them in the following.

3.1 CKM matrix elements

The CKM matrix in the Wolfenstein parametrization is read as:

$$V_{CKM} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4). \tag{5}$$

It contains four parameters: A, λ, ρ and η, in which the first two are well-determined [15]:

$$\lambda = |V_{us}| = 0.2200 \pm 0.0025, \qquad A\lambda^2 = |V_{cb}| = (40.4 \pm 1.3_{stat} \pm 0.9_{theo}) \times 10^{-3}.$$

As to ρ and η, they are kept free except for the constraint $|V_{ub}| = (3.49 \pm 0.24_{stat} \pm 0.55_{theo}) \times 10^{-3}$ [15] and $\sin 2\beta = 0.731 \pm 0.055$ (world averaged) [8].

3.2 Form factors and decay constants

The form factors and decay constants are non-perturbative parameters. The form factors can be extracted from the semi-leptonic decays and/or estimated with some well-defined theories, such as the lattice calculations, QCD sum rules etc.. But the related errors are still sizable. The decay constants can be extracted from the leptonic or electromagnetic decay width with high precision. In the fit, we choose the corresponding numerical values as follows [16, 17, 18, 19]:

$$\begin{array}{lll} f_\pi = 131\text{MeV}, & f_K = 160\text{MeV}, & f_{K^*} = 214\text{MeV}, \\ f_\rho = 210\text{MeV}, & f_\omega = 195\text{MeV}, & f_\phi = 233\text{MeV}, \\ f_q = 140\text{MeV}, & f_s = 176\text{MeV}, & \phi = 39.3^\circ, \\ f_B = (180 \pm 40)\text{MeV}, & & R_{\pi K} = 0.9 \pm 0.1, \\ F_{0,1}^{B\pi}(0) = 0.28 \pm 0.05, & & A_0^{BK^*}(0) = 0.47 \pm 0.07, \\ A_0^{B\rho}(0) = 0.37 \pm 0.06, & & A_0^{B\omega}(0) = A_0^{B\rho}(0), \end{array}$$

where $R_{\pi K} \equiv f_\pi F^{BK}/f_K F^{B\pi}$. In the above, we assume ideal mixing between ω and ϕ, i.e. $\omega = (u\bar{u} + d\bar{d})/\sqrt{2}$ and $\phi = s\bar{s}$. As for $\eta - \eta'$ mixing, we follow the convention in the quark-flavor basis [20, 21] and assume that the charm quark content in $\eta^{(\prime)}$ is negligible:

$$\langle 0|\bar{q}\gamma_\mu\gamma_5 q|\eta^{(\prime)}(p)\rangle = i f^q_{\eta^{(\prime)}} p_\mu, \qquad (q = u, d, s)$$

$$\frac{\langle 0|\bar{u}\gamma_5 u|\eta^{(\prime)}\rangle}{\langle 0|\bar{s}\gamma_5 s|\eta^{(\prime)}\rangle} = \frac{f^u_{\eta^{(\prime)}}}{f^s_{\eta^{(\prime)}}}, \qquad \langle 0|\bar{s}\gamma_5 s|\eta^{(\prime)}\rangle = -i\frac{m^2_{\eta^{(\prime)}}}{2m_s}(f^s_{\eta^{(\prime)}} - f^u_{\eta^{(\prime)}}),$$
$$f^u_\eta = \frac{f_8}{\sqrt{6}}\cos\theta_8 - \frac{f_0}{\sqrt{3}}\sin\theta_0, \qquad f^s_\eta = -2\frac{f_8}{\sqrt{6}}\cos\theta_8 - \frac{f_0}{\sqrt{3}}\sin\theta_0, \tag{6}$$
$$f^u_{\eta'} = \frac{f_8}{\sqrt{6}}\sin\theta_8 + \frac{f_0}{\sqrt{3}}\cos\theta_0, \qquad f^s_{\eta'} = -2\frac{f_8}{\sqrt{6}}\sin\theta_8 + \frac{f_0}{\sqrt{3}}\cos\theta_0,$$
$$F^{B\eta}_{0,1} = F^{B\pi}_{0,1}\Big(\frac{\cos\theta_8}{\sqrt{6}} - \frac{\sin\theta_0}{\sqrt{3}}\Big), \qquad F^{B\eta'}_{0,1} = F^{B\pi}_{0,1}\Big(\frac{\sin\theta_8}{\sqrt{6}} + \frac{\cos\theta_0}{\sqrt{3}}\Big),$$

where the four octet-singlet parameters can be related to three quark-flavor parameters:

$$f_8 = \sqrt{1/3 f_q^2 + 2/3 f_s^2}, \qquad f_0 = \sqrt{2/3 f_q^2 + 1/3 f_s^2},$$
$$\theta_8 = \phi - \arctan(\sqrt{2} f_s/f_q), \qquad \theta_0 = \phi - \arctan(\sqrt{2} f_q/f_s). \tag{7}$$

3.3 The LCDAs of the mesons

The LCDAs of the mesons are basic input parameters in the QCDF approach. The LCDAs of a light pseudoscalar meson are defined as [22, 23]:

$$\begin{aligned}\langle P(p')|\bar{q}_\alpha(y) q_\delta(x)|0\rangle &= \frac{i f_P}{4}\int_0^1 du\ e^{i(up'\cdot y + \bar{u}p'\cdot x)} \\ &\times \left\{ \not{p}'\gamma_5\phi(u) - \mu_P\gamma_5\left(\phi_p(u) - \sigma_{\mu\nu}p'^\mu z^\nu \frac{\phi_\sigma(u)}{6}\right)\right\}_{\delta\alpha},\end{aligned} \tag{8}$$

where $z = y - x$, $\phi(u)$ ($\phi_{p,\sigma}(u)$) is leading twist (twist-3) LCDA, and $\mu_P = m_P^2/(m_1(\mu) + m_2(\mu))$ (here m_1 and m_2 are current masses of the valence quarks of the pseudoscalar meson). Because the current masses of light quarks are difficult to fix, we would like to take

$$r_\eta(1 - \frac{f^u_\eta}{f^s_\eta}) = r_\pi = r_K = r_\chi$$

which is numerically a good approximation. For the related quark masses, we shall follow Ref. [7]:

$$m_s(2\text{GeV}) = (110 \pm 25)\ \text{MeV}, \qquad m_c(m_b) = 1.3\ \text{GeV}, \qquad m_b(m_b) = 4.2\ \text{GeV}.$$

For vector mesons, only longitudinal polarization is involved in $B \to PV$ decays. Furthermore, the contributions of twist-3 LCDAs of vector meson are doubly suppressed by α_s and Λ/m_b, therefore they can be safely disregarded. Then the leading twist LCDA of a longitudinal vector meson is defined as [22, 23]:

$$\langle V_\parallel(p')|\bar{q}_\alpha(y) q_\delta(x)|0\rangle = \frac{f_V m_V}{4}\int_0^1 du\, e^{i(up'\cdot y + \bar{u}p'\cdot x)}\phi_\parallel(u)\not{p}'_{\delta\alpha}/E\,. \tag{9}$$

We shall use the asymptotic forms of the LCDAs for the following discussions:

$$\phi(u) = \phi_\parallel(u) = 6u\bar{u}, \qquad \phi_p(u) = 1, \qquad \phi_\sigma(u) = 6u\bar{u}\,. \tag{10}$$

Strictly speaking, the asymptotic forms are only valid for $\mu \to \infty$. We notice that in Ref. [7], Beneke *et al.* employ an expansion in Gegenbauer polynomials for leading twist π, K LCDAs. However, since there are many light mesons involved in our global fit, if we consider similar expansion for the leading twist LCDAs, many free parameters would be introduced. Fortunately, the corrections to the asymptotic form are numerically not-so-important because they only affect the part of the vertex and penguin corrections(numerically, the readers may refer to Table 3 of Ref. [7] to see the effects of the Gegenbauer expansion). So for simplification, only the asymptotic forms are used in our discussions.

For the wave function of the B meson, only the moment $\int_0^1 d\xi \Phi_B(\xi)/\xi \equiv m_B/\lambda_B$ appears in the factorization formulae. We do not know much about the parameter λ_B and the estimation of Ref. [7] is quoted : $\lambda_B = (350 \pm 150)$ MeV.

4 Global analysis of charmless B decays

In this work, the global analysis is based on the CKMFitter package [2] developed by Höcker *et al.*[6]. The original package includes $B \to hh$ ($h = \pi$ or K) decay channels, and we enlarge it to include $B \to PV$ and $B \to \eta\pi(K)$ decay modes. The Rfit scheme are implemented for statistical treatment. Simply speaking, the Rfit scheme assumes the experimental errors to be pure Gaussians (if the systematic errors are not-so-large) while the theoretical parameters vary freely in a given range. In this spirit, it is similar with 95% Scan Method. One of the main difference is that, the overall χ^2_{min} is assumed to be Gaussian distributed in 95% Scan Method, while for Rfit scheme, the confidence level of the overal χ^2_{min} is computed by means of a Monte Carlo Simulation. The readers may refer to Ref. [6] for details about the Rfit scheme. As to the QCDF expressions for the related decay amplitudes, the readers may read the paper [7, 4] for B $\to$ PP decays and [5] for B $\to$ PV decays.

Compared with pQCD, QCDF requires more input parameters, such as form factors, annihilation parameter X_A and hard spectator parameter X_H, and so on. To make the global analysis appear more persuasive, and at the same time save the computing time, we minimize the number of variables by fixing those insensitive parameters. One example is that we shall use the asymptotic forms of the LCDAs for all final light mesons, and not employ an expansion in Gegenbauer polynomials.

Since power corrections violate factorization, the parameters X_A and X_H are introduced as a model parameterization. But we should be care that, in principle, these parameters are channel-dependent. Fortunately, assuming "factorized" SU(3) breaking, we can see that X_A and X_H are universal separately for $B \to PP$ and $B \to PV$ decay modes. However, there is no way to relate the chiral parameters of the PV channels to those of the PP channels. So we have to introduce, besides X_A^{PP} and X_H^{PP}, additional parameters X_A^{PV} and X_H^{PV} for $B \to PV$ decays.

In Refs. [7, 27], Beneke *et al.* present a detailed analysis on $B \to \pi\pi$, πK with the QCDF approach. They show an impressive agreement between experiments and the QCDF predictions: $\chi^2 \approx 0.5$ for six decay channels. Their best fit results favor γ around

[2]http://ckmfitter.in2p3.fr

90° which seems not so consistent with the standard global fit of the CKM matrix elements using information from semileptonic B decays, K-$\bar{K}$ mixing and B-$\bar{B}$ mixing. Even for γ around 60°, $\chi^2 \approx 1$ is still good enough to be acceptable. In QCDF, these six decay channels are sensitive to several input parameters: the CKM parameters $|V_{ub}|$ and angle γ (or equivalently ρ and η), form factors $F^{B\pi}$ and F^{BK}, annihilation-related parameters X_A and f_B/λ_B, current quark mass m_s. These parameters vary freely only in a given range which is either determined by experimental measurements ($|V_{ub}|$), estimations with QCD Sum Rules and/or lattice calculations (form factors and decay constants) or well-educated guesswork (X_A). So it is really non-trivial for the achieved agreement between the QCDF predictions and the experimental measurements.

In this work, we will extend the global analysis to include fourteen $B \to PP$ and PV decay modes (see Table 1). Notice that hard spectator parameter X_H^{PV} is numerically unimportant for the branching ratios except for a_2-related tree-dominated decays [5], and even for a_2-related decays, it brings at most 20% uncertainties. So compared with the global analysis of $B \to \pi\pi$, πK [7], our extension would include seven $B \to PV$ channels and newly-observed $B \to \eta\pi$ decay, while only three new sensitive parameters — form factor $A_0^{B\rho}$, and complex variable X_A^{PV} — would be involved. Therefore we can have a more stringent test on the QCDF predictions which should give some interesting information.

Recently BaBar and Belle also give strong constraint on direct CP violations for many charmless hadronic B decay channels. Their search show that direct CP-violating asymmetries are generally small. Within the QCDF framework, strong phases are either α_s or Λ/m_b suppressed, which also lead to small direct CP violations in general. However, only radiative corrections are perturbatively computable in QCDF, while power corrections break the factorization in general. Considering that Λ/m_b is numerically comparable with α_s, the QCDF calculations on direct CP violations are probably qualitative. So the experimental constraints on direct CP violations are not implemented in this global analysis.

Before doing the global fit, the readers may notice that, some decay modes are not included in the global analysis although they have been observed. These decay channels are listed in Table 2, and we will discuss these channels later.

4.1 Main results of the global fit

When the decay channels in Table 1 are concerned, the global fit shows that the QCDF predictions are well consistent with the experimental measurements: The results in the $(\overline{\rho}, \overline{\eta})$ plane are shown in Fig. 3 where $\chi^2_{min} = 4.2$ for fourteen decay channels. As an illustration, in Table 3, we list the best fit values of the global analysis for the related $B \to PP$,PV decay modes with and without chiral-related contributions. Notice that two sets of the best fit values (with or without chirally enhanced contributions) are obtained with different input parameters. It indicates that the newly observed $B^0 \to \omega K^0$ decay can be included in the global fit without any difficulty, and that the decay $B^+ \to \eta\rho^+$ is hopeful to be observed soon. The corresponding theoretical inputs for the best fit values including chirally enhanced corrections are also reasonable: $|V_{ub}| = 3.57 \times 10^{-3}$, $\gamma = 79^\circ$, $F^{B\pi} = 0.24$, $A_0^{B\rho} = 0.31$, $m_s = 85\ MeV$, $\mu = 2.5\ GeV$, $f_B = 220\ MeV$, $\rho_A^{PP} = 0.5$,

Table 1: Experimental data of CP-averaged branching ratios for some charmless B decay modes in unit of 10^{-6}. The following decay channels are the experimental input of the global fit.

BF($\times 10^6$)	CLEO [24]	BaBar[25]	Belle[26]	Average
$B^0 \to \pi^+\pi^-$	$4.3^{+1.6}_{-1.4} \pm 0.5$	$4.7 \pm 0.6 \pm 0.2$	$5.4 \pm 1.2 \pm 0.5$	4.77 ± 0.54
$B^+ \to \pi^+\pi^0$	$5.4^{+2.1}_{-2.0} \pm 1.5$	$5.5^{+1.0}_{-0.9} \pm 0.6$	$7.4^{+2.3}_{-2.2} \pm 0.9$	5.78 ± 0.95
$B^0 \to K^+\pi^-$	$17.2^{+2.5}_{-2.4} \pm 1.2$	$17.9 \pm 0.9 \pm 0.7$	$22.5 \pm 1.9 \pm 1.8$	18.5 ± 1.0
$B^+ \to K^+\pi^0$	$11.6^{+3.0}_{-2.7}{}^{+1.4}_{-1.3}$	$12.8^{+1.2}_{-1.1} \pm 1.0$	$13.0^{+2.5}_{-2.4} \pm 1.3$	12.7 ± 1.2
$B^+ \to K^0\pi^+$	$18.2^{+4.6}_{-4.0} \pm 1.6$	$17.5^{+1.8}_{-1.7} \pm 1.3$	$19.4^{+3.1}_{-3.0} \pm 1.6$	18.1 ± 1.7
$B^0 \to K^0\pi^0$	$14.6^{+5.9}_{-5.1}{}^{+2.4}_{-3.3}$	$10.4 \pm 1.5 \pm 0.8$	$8.0^{+3.3}_{-3.1} \pm 1.6$	10.2 ± 1.5
$B^+ \to \eta\pi^+$	< 5.7	< 5.2	$5.3^{+2.0}_{-1.7} (< 8.2)$	< 5.2
$B^0 \to \pi^\pm\rho^\mp$	$27.6^{+8.4}_{-7.4} \pm 4.2$	$28.9 \pm 5.4 \pm 4.3$	$20.8^{+6.0}_{-6.3}{}^{+2.8}_{-3.1}$	25.4 ± 4.3
$B^+ \to \pi^+\rho^0$	$10.4^{+3.3}_{-3.4} \pm 2.1$	< 39	$8.0^{+2.3}_{-2.0} \pm 0.7$	8.6 ± 2.0
$B^0 \to K^+\rho^-$	$16.0^{+7.6}_{-6.4} \pm 2.8$		$11.2^{+5.9}_{-5.6}{}^{+1.9}_{-1.8}$	13.1 ± 4.7
$B^+ \to \phi K^+$	$5.5^{+2.1}_{-1.8} \pm 0.6$	$9.2 \pm 1.0 \pm 0.8$	$10.7 \pm 1.0^{+0.9}_{-1.6}$	8.9 ± 1.0
$B^0 \to \phi K^0$	$5.4^{+3.7}_{-2.7} \pm 0.7$	$8.7^{+1.7}_{-1.5} \pm 0.9$	$10.0^{+1.9}_{-1.7}{}^{+0.9}_{-1.3}$	8.6 ± 1.3
$B^+ \to \eta\rho^+$	< 10		< 6.2	< 6.2
$B^0 \to \omega K^0$		$5.9^{+1.7}_{-1.5} \pm 0.9$		5.9 ± 1.9

$\phi_A^{PP} = 10°$, $\rho_A^{PV} = 1$, $\phi_A^{PV} = 330°$. As to F^{BK}, there is no strong constraint and the range $[0.24, 0.30]$ is acceptable from the current global analysis. In Ref. [27], it argues that chirally enhanced corrections are not indispensable for $B \to \pi\pi$ and πK decays. However, we can see from Table 3 that, especially for penguin-dominated $B \to PV$ decays, chirally enhanced contributions play an important role. Note that this point is not firmly established: There are significant experimental errors on $B^0 \to K^+\rho^-$, ωK^0 decays. If these two channels were excluded, we could see from Table 3 that it is still acceptable without chiral-related contributions. However, $\pi^+ K^{*0}$ decay also implies large chiral contributions: Without chirally enhanced corrections, it is clear that

$$\frac{\mathcal{A}(B^+ \to \pi^+ K^{*0})}{\mathcal{A}(B^+ \to \pi^+ K^0)} \simeq \frac{f_{K^*}}{f_K} \frac{a_4}{a_4 + a_6} \simeq 1/2 \,, \tag{11}$$

Table 2: Measurements which are not included in the global analysis.

BF($\times 10^6$)	CLEO[24]	BaBar[25]	Belle[26]	Average
$B^+ \to \eta K^+$	< 6.9	< 6.4	$5.2^{+1.7}_{-1.5} (< 7.7)$	< 6.4
$B^+ \to \pi^+ K^{*0}$	< 16	$15.5 \pm 3.4 \pm 1.8$	$16.2^{+4.1}_{-3.8} \pm 2.4$	15.8 ± 3.0
$B^0 \to \pi^- K^{*+}$	$16^{+6}_{-5} \pm 2$		$26.0 \pm 8.3 \pm 3.5$	19.0 ± 4.9
$B^+ \to \eta K^{*+}$	$26.4^{+9.6}_{-8.2} \pm 3.3$	$22.1^{+11.1}_{-9.2} \pm 3.3$	$26.5^{+7.8}_{-7.0} \pm 3.0$	25.4 ± 5.3
$B^0 \to \eta K^{*0}$	$13.8^{+5.5}_{-4.6} \pm 1.6$	$19.8^{+6.5}_{-5.6} \pm 1.7$	$16.5^{+4.6}_{-4.2} \pm 1.2$	16.4 ± 3.0
$B^+ \to \omega K^+$	< 8	< 4	$9.9^{+2.7}_{-2.4} \pm 1.0$	
$B^+ \to \omega\pi^+$	$11.3^{+3.3}_{-2.9} \pm 1.5$	$6.6^{+2.1}_{-1.8} \pm 0.7$	< 8.2	

which means

$$\mathcal{B}(B^+ \to \pi^+ K^{*0}) \simeq \frac{1}{4}\mathcal{B}(B^+ \to \pi^+ K^0) \simeq 5 \times 10^{-6}\,. \tag{12}$$

It is three times smaller than the experimentally central value (see Table 2). Thereby further measurements with higher precision on the penguin-dominated $B \to PV$ decays will clarify the role of the chirally enhanced contributions. We will return back to πK^* channel later and explain why we do not include this mode for the global fit.

Table 3: The best fit values using the global analysis with and without chiral-related contributions for $B \to PP$ and PV decays. "No chiral" means the best fit value neglecting the chirally enhanced hard spectator contributions and the annihilation topology. The branching ratios are in unit of 10^{-6}. The experimental data are the uncorrelated average of measurements of BaBar, Belle and CLEO (see data in the last column of Table 1).

Mode	$B^0 \to \pi^+\pi^-$	$B^+ \to \pi^+\pi^0$	$B^0 \to K^+\pi^-$	$B^+ \to K^+\pi^0$	$B^+ \to K^0\pi^+$
Exp.	4.77 ± 0.54	5.78 ± 0.95	18.5 ± 1.0	12.7 ± 1.2	18.1 ± 1.7
Best Fit	4.82	5.35	19.0	11.4	20.1
No chiral	5.68	3.25	18.8	12.6	20.2
Mode	$B^0 \to \pi^0 K^0$	$B^+ \to \eta\pi^+$	$B^0 \to \rho^\pm\pi^\mp$	$B^+ \to \rho^0\pi^+$	$B^+ \to \eta\rho^+$
Exp.	10.2 ± 1.5	< 5.2	25.4 ± 4.3	8.6 ± 2.0	< 6.2
Best Fit	8.2	2.8	26.7	8.9	4.6
No chiral	7.3	1.8	29.5	8.5	3.8
Mode	$B^+ \to \phi K^+$	$B^0 \to \phi K^0$	$B^0 \to K^+\rho^-$	$B^0 \to \omega K^0$	
Exp.	8.9 ± 1.0	8.6 ± 1.3	13.1 ± 4.7	5.9 ± 1.9	
Best Fit	8.9	8.4	12.1	6.3	
No chiral	7.1	6.7	5.1	1.2	

It is known that, the penguin-to-tree ratio $|P_{\pi\pi}/T_{\pi\pi}|$ is very useful for the extraction of CKM angle α [28]. In Ref. [7], the authors show that $|P_{\pi\pi}/T_{\pi\pi}| = (28.5 \pm 5.1 \mp 5.7)\%$ with the QCDF approach using the default values for the chirally enhanced corrections, i.e. $X_H = X_A = \ln(m_B/\Lambda_h)$. When considering the uncertainties of the $X_{A,H}$ parameters, the theorectical errors would be even larger. So it should be very interesting to get the preferred $|P/T|$ [3] ratio from the global analysis. Till now the asymptotic LCDAs are used for the global fit because the branching ratios are numerically not so sensitive to the corrections to the asymptotic form. But for the penguin-to-tree ratio, the case is different and we should consider the Gegenbauer polynomials expansion for the leading twist LCDAs of the π, K mesons. We find that, compared with the estimation $|P/T| = 0.276 \pm 0.064$ [28] (including $SU(3)$ breaking effects), the global fit prefers a suprisingly large value: $|P_{\pi\pi}/T_{\pi\pi}| \simeq 0.41$. The reason may be that penguin annihilation effects increase the penguin amplitudes, as discussed in [7]. Considering the relatively large

[3]The decay amplitudes fot $B_d^0 \to \pi^+\pi^-$ are [28]

$$\mathcal{A}(B_d \to \pi^+\pi^-) = -(|T|e^{i\delta_T}e^{i\gamma} + |P|e^{\delta_P}),$$

where δ_T and δ_P are strong phases.

model-dependence of this ratio within the QCDF framework, the best fit value may be not so meaningful to reduce ambiguity in the determination of $\sin 2\alpha$. However, even assuming that it is acceptable for the global fit with $\chi^2/N_{dof} \leq 1$ (N_{dof} denotes the number of degrees), the ratio $|P_{\pi\pi}/T_{\pi\pi}|$ is still larger than 0.3. This result is quite interesting, although undoubtedly it needs further test with larger data samples.

The confidence levels of angle γ and some interesting decay channels are given in Figure 3 and Figure 4, respectively. It is encouraging that the favored angle γ is around 79° which is somewhat larger but still consistent with the standard CKM global fit. $\mathcal{B}(B^0 \to \pi^0\pi^0)$, which is crucial for a clean extraction of angle α, is predicted to be around 1×10^{-6}. So it is hopeful to be observed in the near future. For the pure annihilation decay $B^0 \to K^+K^-$, although the update upper limit has been very stringent, the branching ratio is predicted to be still several times smaller than that: roughly 10^{-7}.

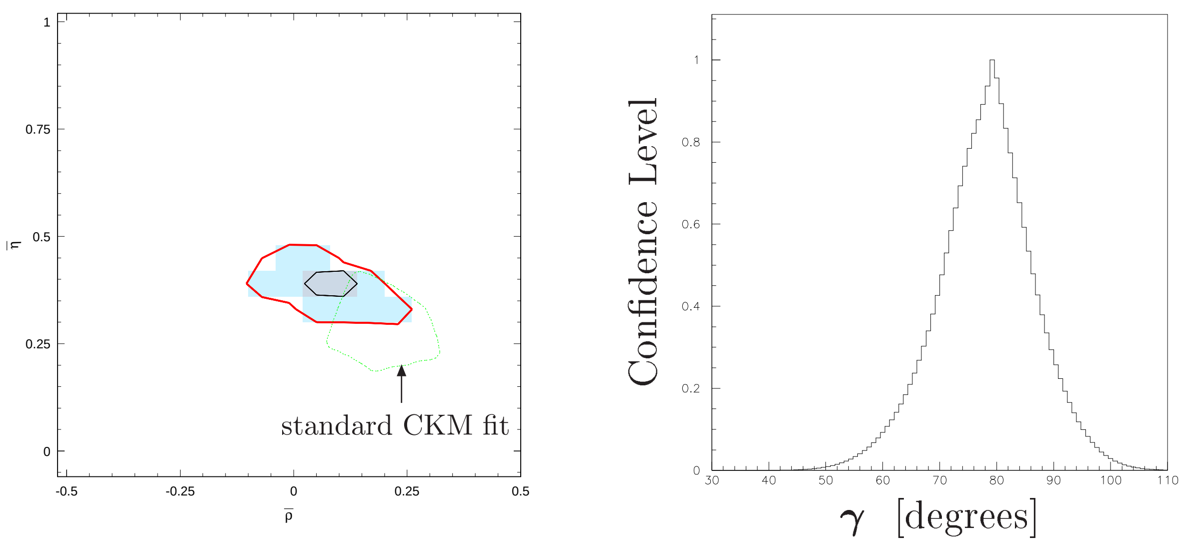

Figure 3: Left plot: confidence level in the $(\overline{\rho}, \overline{\eta})$ plane for the global fit. The contours with shaded area inside indicate the regions of $\geq 90\%$ and $\geq 5\%$ Confidence levels. Right plot: The confidence level for angle γ in unit of degree.

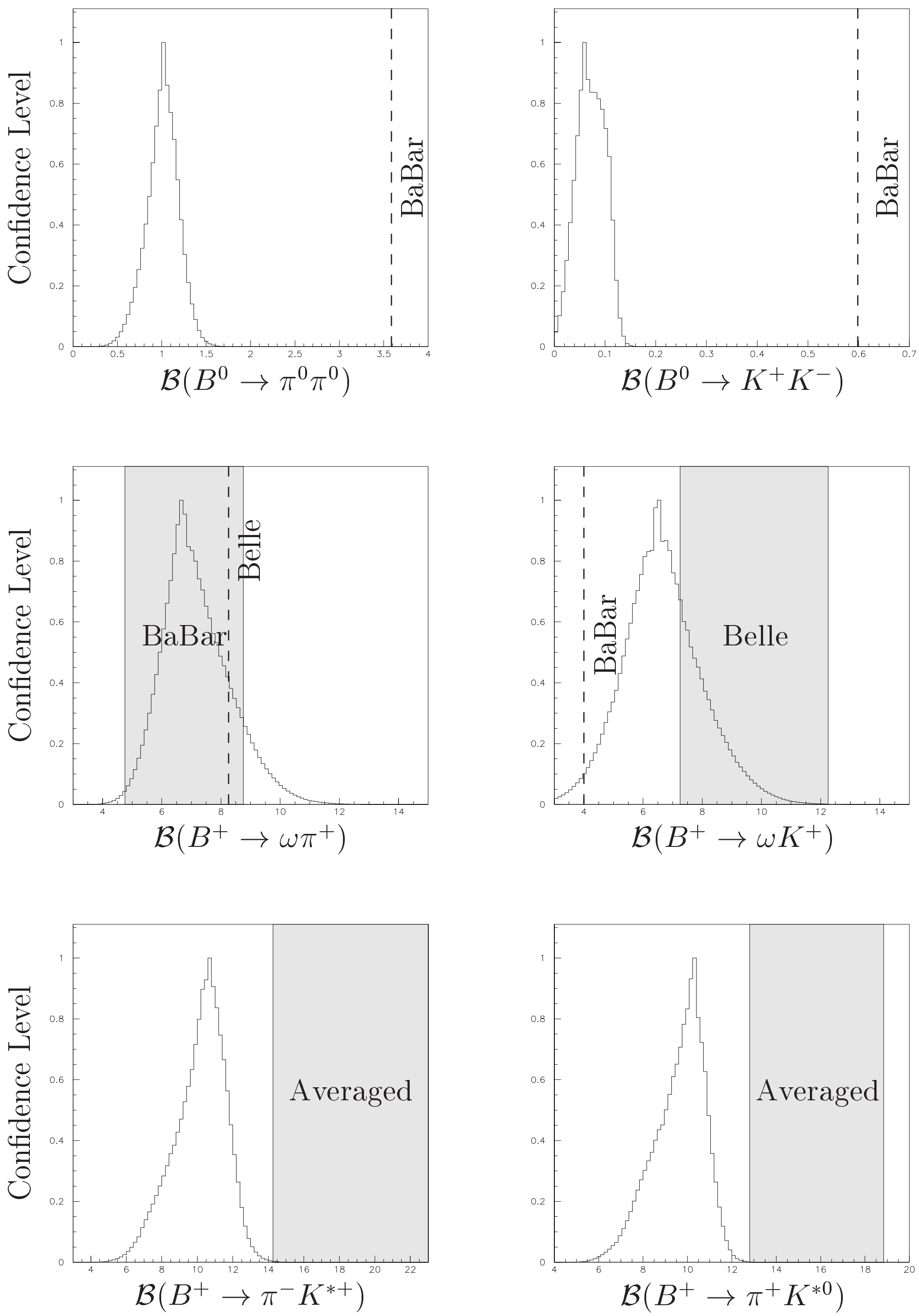

Figure 4: The confidence levels for some selected decay channels. The branching ratios are in unit of 10^{-6}. The dashed lines denote the experimental upper limits, the gray bands denote the experimental measurements with 1σ error.

4.2 The decay modes listed in Table 2

Now let us discuss in detail why we do not include the decay modes listed in Table 2 for the global analysis.

For $B^+ \to \omega\pi^+(K^+)$, the measurements of Belle are not so consistent with those of BaBar and CLEO. Assuming $A_0^{B\omega} = A_0^{B\rho}$ which should be a good approximation, the confidence levels for these two decay channels are shown in Figure 4. For $\omega\pi^+$ decay, the best fit value is 6.66×10^{-6} which is consistent with the measurements of BaBar and Belle. The best fit value for ωK^+ decay is 6.25×10^{-6} which is consistent with the Belle observation but larger than the upper limit given by BaBar.

As to $B \to \eta K^*$ decays, the branching ratios depend on the form factor $A_0^{BK^*}$. Note that there are no other observed PV decay channels relying on this form factor, it is more or less trivial to include $B \to \eta K^*$ decays, since in some sense $A_0^{BK^*}$ acts essentially as a free parameter in the global fit especially considering the large experimental errors on these decay channels. One might argue that the observed $B \to \phi K^*$ decay also depends on the form factor $A_0^{BK^*}$. But this decay channel requires new annihilation parameter X_A^{VV} for $B \to VV$ decays. Hence it may be better to first have a restricted constraint on X_A^{VV} with more $B \to VV$ decay modes to be observed. Then more precise data on $B \to \phi K^*$, ηK^* could overconstrain the form factor $A_0^{BK^*}$ and give a more stringent test on the QCDF approach.

The decay mode $B^+ \to \eta K^+$ is recently observed by Belle. Within the QCDF framework, the corresponding amplitude is proportional to $f_K F^{B\eta}(a_4+r_\chi a_6)+f_\eta^s F^{BK}(a_4+r_\chi a_6)$. Notice that $f_\eta^s < 0$, large cancellation occurs which lead to much smaller branching ratio compared with the experimental data. But we do not worry about it due to several reasons:

- Firstly, it relates to the special property of $\eta^{(\prime)}$ which has anomaly coupling to two gluons. Specifically, the digluon fusion mechanism [29] where one gluon comes from $b \to s$ decay vertex, and the other from spectator quark, is presumed to account for the large branching ratios of $B \to \eta' K$ decays. Although it is arguable that whether the digluon mechanism is perturbatively calculable or not, the contribution should be proportional to the coupling $\langle 0|G\tilde{G}|\eta^{(\prime)}\rangle$. As we know that

$$\frac{\langle 0|\frac{\alpha_s}{4\pi}G\tilde{G}|\eta\rangle}{\langle 0|\frac{\alpha_s}{4\pi}G\tilde{G}|\eta'\rangle} = \left(\frac{M_\eta}{M_{\eta'}}\right)^2 \cot\phi \simeq \frac{1}{5} \quad \text{and} \quad \left|\frac{\mathcal{A}^{exp}(B\to\eta K)}{\mathcal{A}^{exp}(B\to\eta' K)}\right| \simeq \frac{1}{4}\,,$$

  it means

$$\left|\frac{\mathcal{A}^{g}(B\to\eta K)}{\mathcal{A}^{exp}(B\to\eta K)}\right| \sim \left|\frac{\mathcal{A}^{g}(B\to\eta' K)}{\mathcal{A}^{exp}(B\to\eta' K)}\right|$$

  where A^g denotes the amplitude of digluon fusion mechanism. So if the digluon mechanism was important for $B \to \eta' K$, it should be also important for $B \to \eta K$.

- Secondly, we know that when the leading power terms are abnormally small, the next-to-leading power contributions become potentially important. Remembering that there is no known systematic way to estimate power corrections, the QCDF estimation on this channel is probably correct only at the order of magnitude.

- Recently, Beneke and Neubert [27] propose a novel possibility: for the annihilation contributions, two gluons may radiate from the spectator quark and form a $\eta^{(\prime)}$ meson. In this case, it is leading power contribution. Furthermore it breaks the factorization and therefore new non-perturbative parameter is needed to parameterize its contribution.

From above discussions, it is clear that theoretically great efforts are needed to quantitatively understand $B \to \eta^{(\prime)} K$ decays.

The real trouble is $B \to \pi K^*$ decays. Let us take $B^+ \to \pi^+ K^{*0}$ as an example. In QCDF, approximately we have

$$\mathcal{A}(B^+ \to \pi^+ K^{*0}) \quad \propto a_4 f_{K^*} F^{B\pi} \times const. + f_B f_{K^*} f_\pi b_3(V,P)\,, \tag{13}$$

$$\mathcal{A}(B^+ \to \phi K^+) \quad \propto a_4 f_\phi F^{BK} \times const. + f_B f_\phi f_K b_3(V,P)\,. \tag{14}$$

Assuming $F^{BK}/F^{B\pi} \approx f_K/f_\pi$, then

$$\frac{\mathcal{A}(B^+ \to \pi^+ K^{*0})}{\mathcal{A}(B^+ \to \phi K^+)} \approx \frac{f_{K^*} F^{B\pi}}{f_\phi F^{BK}} < 1\,.$$

So $\mathcal{B}(B^+ \to \pi^+ K^{*0})$ should be smaller than or at most comparable with $\mathcal{B}(B^+ \to \phi K^+)$. Unfortunately, the updated experimental measurements do not support it:

$$\mathcal{B}(B^+ \to \pi^+ K^{*0}) = (15.8 \pm 3.0)\times 10^{-6}\,, \qquad \mathcal{B}(B^+ \to \phi K^+) = (8.8 \pm 1.0)\times 10^{-6}.$$

General speaking, we do not anticipate any novel mechanism for this channel because it would have similar influence on $B \to \pi K$ decays. So presently there is nothing we can do from the QCDF side. With the global fit, the confidence level for $B \to \pi K^*$ is displayed in Figure 4, from which we can see that $\mathcal{B}(B^+ \to \pi^+ K^{*0})$ is comparable with $\mathcal{B}(B^+ \to \phi K^+)$ as expected. The preferred branching ratios are somewhat smaller than the experimental measurements for both $\pi^+ K^{*0}$ and $\pi^- K^{*+}$ modes. Fortunately the current experimental errors are quite large. We anticipate that further precise measurements would prefer smaller branching ratios for these two decay channels.

5 Summary

The QCD factorization is a promising method for charmless two-body B decays, which are crucial for the determination of Unitarity Triangle. With the successful running of B factories, many $B \to PP$ and PV decay modes have being observed. We can do a global analysis to check whether the predictions of the QCD factorization are consistent with the measurements. Since there are many parameters involved in the global analysis, we try to minimize the number of free QCD parameters to make the global analysis appear more persuasive. Hence, the asymptotic forms are used for the light-cone distribution amplitudes of the light pseudoscalar and vector mesons. For chirally enhanced parameter, it is a good approximation to take $r_\eta = r_\pi = r_K = 2m_K^2/m_b(m_s + m_u)$. Assuming "factorized" SU(3) breaking, the chirally enhanced parameters $X_{A,H}$ are separately universal for $B \to PP$ and PV decays. However, $X_{A,H}^{PP}$ and $X_{A,H}^{PV}$ are independent parameters because there is no approximate symmetry to relate $B \to PP$ and $B \to PV$ decays.

With the above set of parameters, we enlarge the CKMFitter package to include more charmless decay channels and do the global analysis. It is shown that the QCDF predictions are basically in good agreement with the experiments. It is encouraging to see that the favored angle γ are roughly consistent with the standard CKM global fit. It is quite interesting to see that the chirally enhanced corrections may play an important role in penguin-dominated $B \to PV$ decays. The penguin-to-tree ratio $P_{\pi\pi}/T_{\pi\pi}$ is important for the extraction of the CKM angle α. The global analysis favors this ratio to be larger than 0.3 with χ^2 per number of degree smaller than 1.

Notice that the observed decays ηK^+, ηK^*, πK^*, $\omega\pi^+$, ωK^+ are not included in the analysis. In the paper we discuss these decay channels in detail. Among these channels, only the decays $B \to \pi K^*$ are somewhat troublesome. In QCDF, $\mathcal{B}(B^+ \to \pi^+ K^{*0})$ should be smaller than or at most comparable with $\mathcal{B}(B^+ \to \phi K^+)$, which is not so consistent with the experimental observation. In fact, the global analysis prefers somewhat smaller branching ratios for both $\pi^+ K^{*0}$ and $\pi^- K^{*+}$ decay modes. Fortunately the related experimental errors are quite large at present, it is anticipated that further measurements with higher precision would observe smaller branching ratios. We also give the confidence levels for some selected decay channels: $B^0 \to \pi^0\pi^0$, K^+K^- and $B^+ \to \omega\pi^+(K^+)$.

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References

[1] M. Beneke, G. Buchalla, M. Neubert and C.T. Sachrajda, Phys. Rev. Lett. **83**, 1914 (1999).

[2] Y. Y. Keum, H. N. Li, A. I. Sanda, Phys. Rev. **D63**, 054008 (2001); Phys. Lett. **B504**, 6 (2001).

[3] M. Ciuchini, R. Contino, E. Franco, G. Martinelli and L. Silvestrini, Nucl. Phys. **B512**, 3 (1998).

[4] D.S. Du, H.J. Gong, J.F. Sun, D.S. Yang and G.H. Zhu, Phys. Rev. **D65**, 074001 (2002).

[5] D.S. Du, H.J. Gong, J.F. Sun, D.S. Yang and G.H. Zhu, Phys. Rev. **D65**, 094025 (2002), and Erratum to be published in Phys. Rev. D.

[6] see for example, A. Höcker, H. Lacker, S. Laplace and F.Le. Diberder, Eur. Phys. J. **C21**, 225 (2001); M. Ciuchini *et al.*, JHEP **0107**, 013 (2001).

[7] M. Beneke, G. Buchalla, M. Neubert and C.T. Sachrajda, Nucl. Phys. **B606**, 245 (2001).

[8] B. Aubert *et al.*(BaBar Collab.), hep-ex/0207042; K. Abe *et al.*(Belle Collab.), hep-ex/0208025.

[9] For a review, see G. Buchalla, A.J. Buras and M.E. Lautenbacher, Rev. Mod. Phys. **68**, 1125 (1996).

[10] J.D. Bjorken, Nucl. Phys. (Proc. Suppl.) **B11**, 325 (1989).

[11] M. Beneke, G. Buchalla, M. Neubert and C.T. Sachrajda, Nucl. Phys. **B591**, 313 (2000).

[12] C.W. Bauer, S. Fleming, D. Pirjol and I.W. Stewart, Phys. Rev. **D63**, 114020 (2001).

[13] D.S. Du, D.S. Yang and G.H. Zhu, Phys. Rev. **D64**, 014036 (2001); Phys. Lett. **B509**, 263 (2001).

[14] M. Neubert and B.D. Pecjak, JHEP **0202**, 028 (2002).

[15] A. Höcker, H. Lacker, S. Laplace and F.Le. Diberder, hep-ph/0112295, To appear in the proceedings of 9th International Symposium on Heavy Flavor Physics, Pasadena, California, 10-13 Sep 2001.

[16] A. Ali, G. Kramer and C.D. Lü, Phys. Rev. **D58**, 094009 (1998).

[17] M. Neubert and B. Stech, Adv.Ser.Direct.High.Energy Phys.**15**, 294 (1998).

[18] T. Feldmann and P. Kroll, hep-ph/0201044, Invited talk at Workshop on Eta physics: Prospects of Precision Measurements with the CELSIUS/WASA Facility, Uppsala, Sweden, 25-27 Oct 2001.

[19] P. Ball, JHEP **9809**, 005 (1998); P. Ball and V.M. Braun, Phys. Rev. **D58**, 094016 (1998).

[20] H. Leutwyler, Nucl.Phys.Proc.Suppl. **64**, 223 (1998);

[21] T. Feldmann, P. Kroll and B. Stech, Phys. Rev. **D58**, 114006 (1998); Phys. Lett. **B449**, 339 (1999).

[22] P. Ball, V.M. Braun, Y. Koike and K. Tanaka, Nucl. Phys. **B529**, 323 (1998).

[23] M. Beneke and T. Feldmann, Nucl. Phys. **B592**, 3 (2001).

[24] D. Cronin-Hennessy *et al.* (CLEO Collab.), Phys. Rev. Lett. **85**, 515 (2000); S.J. Richichi *et al.* (CLEO Collab.), Phys. Rev. Lett. **85**, 520 (2000); C.P. Jessop *et al.* (CLEO Collab.), Phys. Rev. Lett. **85**, 2881 (2000); R.A. Briere *et al.* (CLEO Collab.), Phys. Rev. lett. **86**, 3718 (2001); E. Eckhart *et al.* (CLEO Collab.), hep-ex/0206024.

[25] B. Aubert *et al.* (BaBar Collab.), hep-ex/0207065; hep-ex/0207055; hep-ex/0107037; hep-ex/0107058; hep-ex/0109007; Phys. Rev. Lett. **87**, 221802 (2001); A. Bevan (BaBar Collab.), talk presented at ICHEP2002, Amsterdam, Holland, 24-31 July 2002. P. Bloom (BaBar Collab.), talk at Meeting of the Division of Particles and Fields, American Physical Society, Williamsburg, Virginia, 24-28 May 2002.

[26] B.C.K. Casey *et al.* (Belle Collab.), hep-ex/0207090; R.S. Lu *et al.* (Belle Collab.), hep-ex/0207019; A. Gordon *et al.* (Belle Collab.), hep-ex/0207007; P. Chang (Belle Collab.), talk presented at ICHEP2002, Amsterdam, Holland, 24-31 July 2002; K.F. Chen (Belle Collab.), talk presented at ICHEP2002, Amsterdam, Holland, 24-31 July 2002; H.C. Huang (Belle Collab.), talk at 37th Rencontres de Moriond on Electroweak Interactions and Unified Theories, Les Arcs, France, 9-16 March 2002, to appear in the Proceedings.

[27] M. Beneke, hep-ph/0207228, talk given at Flavor Physics and CP Violation(FPCP), Philadelphia, Pennsylvania, 16-18 May 2002.

[28] M. Gronau and J.L. Rosner, Phys. Rev. **D65**, 013004 (2002) [Erratum, ibid. **D65** 079901 (2002)]; ibid. **D65**, 093012 (2002); hep-ph/0205323.

[29] D.S. Du, C.S. Kim and Y.D. Yang, Phys. Lett. **B426**, 133 (1998); M.R. Ahmady, E. Kou and A. Sugamoto, Phys. Rev. **D58**, 014015 (1998); A.L. Kagan and A.A. Petrov, hep-ph/9707354; A.L. Kagan, hep-ph/9806266.